Safety and Security of Energy Supply in Lithuania

Strategic Insights, Volume VII, Issue 7 (February 2008)

by Vaida Matuziene and Juozas Augutis

Introduction

The main problems and tasks of safety and security of energy supply are written in the Green Paper (2006) issued by the European Commission (EC). The principal priorities of the strategy named by the EC are the creation of a competitive local energy market, the diversification of energy sources, solidarity, productive development, innovations and technologies, and common external energy politics.

On 2003 it was accepted, and as such was called "energy packet." This is the proposal for the European Union (EU) directives:

- A directive to safeguard Security of Supply and Infrastructure investments in electricity, proposing to require construction of enough infrastructures to guarantee security of electricity supply; either of power plants or power line interconnections;
- A directive to increase energy efficiency by 1 percent per year and promote energy services;
- A revision of the guidelines for Trans-European Networks on electricity and gas, to promote more interconnections;
- A regulation on cross-border trade in gas, to strengthen the gas market.

The energy sector is one of the most significant among sectors in the country by importance, number of personnel (about 14 percent of industry personnel), total value of long-term capital of energy enterprises (about 25 percent of all capital of the country's enterprises) and expenses for imported energy sources.

The successful operation of all Lithuanian industrial sectors, the rising living standard and national security of country are mainly dependent on the stability of the energy sector, energy costs, and the reliability of energy supply.

The problem is very relevant for the Lithuania, the EU, and all other countries. Lithuania develops its national security program, and energy security is one of the main parts in it. Reliable, sustainable and effective energy consumption is the main requirement for the National Energy Consumption Efficiency Improvement Program for 2011-2015 (2001). A lot of attention is paid to energy security in Lithuanian energy strategy (2007) as well.

Present Situation of Lithuanian Energy Security of Supply

Lithuanian situation of safety and security of energy supply is quite complicated comparing to other European countries: few countries supply primary energy sources, there aren't networks of gas, oil and electricity to Western Europe, transmission network needs modernization.

Nuclear still is the main source of electric energy in Lithuania: it covers 60—86 percent of total electricity production. Two RBMK type reactors have been built in Lithuania. It was the most advanced version of the former Soviet Union channel type reactor design series. Presently Ignalina NPP operates one reactor (unit 2). The unit 1 was closed in 2004 under joint Lithuania and EU agreement. The unit 2 is scheduled to be closed in 2009.

Nuclear energy in Lithuania is imported only from Russia, taking into account the fact that reactors operating in Ignalina Nuclear Power Plant (NPP) are RBMK (reactor of high power of the channel) type, for which fuel is producing only in Russia. In spite of that nuclear energy is considered as local energy resource because of its possibility of accumulation and low intensity of daily using. Nuclear fuel has great resistance to short interferences of energy supply. On the other hand nuclear energetic is very sensitive to breakdowns. On the occurrence big breakdown it could be stopped all NPP for the shorter or longer time, no matter in what country or which NPP. Juska and Miskinis collected statistics (2005, 2006) that capacity of power stations reaches almost 5000 MW. 26 percent of capacity generates NPP, 53 percent—thermal power plants, 21 percent—hydropower plants (including capacity of Kruonis Pumped Storage Plan) in Lithuania. So closing of Ignalina NPP reactor in 2009 is the main challenge for development of energy system and energy security of supply in Lithuania.

Lithuanian transfer network is enough integrated only to neighbor energy systems:

- four 330 kV and three 110 kV power transmission lines connect to Latvia energy system;
- five 330 kV and seven 110 kV power transmission lines connect to Belarus energy system
- three 330 kV and three 110 kV power transmission lines connect to Kaliningrad district of Russian Federation.

Maximum possible flows of capacity to neighboring countries, when network scheme is normal, are presented in the Table 1.

By the way deficit and import of electric energy is typical for Latvija. There are no connecting to energy system of the neighboring Latvia and other west Europe countries. That's why in the national program (2001) one of energy main points is to built strategical connections to Poland and Sweden.

At the moment, natural gas, including natural gas used as raw material for fertilize production, comprises 28.4 percent in the primary energy balance. As said in the National energy strategy (2007) 3.8 billion cubic meters of it was imported in 2005. 100 percent of natural gas is imported from Russia. The capability of incoming gas pipes reaches 6 billion cubic meters per year—says national program of energy consumption (2001). Lithuania transfers approximately 0.72 billion cubic meters of gas by transit to Kaliningrad district of Russian Federation. Lithuanian gas supply network is connected to Latvian gas pipes network, but it isn't connected to Western Europe gas network. Under the necessity it would be possible to transfer up to 500 million cubic meters of gas per year through Latvia, however capacities of natural gas supply to Latvia are very limited.

In Lithuanian oil sector operate refinery "Mazeikiu nafta" with import export terminal Butinge and terminal of export—import company "Klaipedos nafta." The only Baltic refinery of joint stock company "Mazeikiu nafta" in 2005 reprocessed 8,9 mln. tons of oil.

Four companies work on oil extraction in Lithuania: “Geonafta,” “Minijos nafta,” “Genciu nafta,” and “Manifoldas.” In 2005 there were extracted 220 thousands tons of oil. Raw oil to Lithuanian can be imported from different countries. But it is imported from Russia, Kazakhstan via Butinge terminal.

Historically, the primary feedstock has been Russian crude oil transported via the Druzhba pipeline, however the relevant branch of this system has been closed in Russian territory since July 2006, apparently for repairs or political reasons. Crude oil is now being supplied by the Butinge Terminal.

District heating sector in Lithuania is centralized and needs modernization. There are no interurban or international pipelines. Because of these reasons it is important to warrant secure of supply.

Presently centralist and decentralist heat methods in Lithuania composes in 50 percent in total heat generation balance. The biggest part of fuel output for heat generation makes natural gas—80.6 percent (See: Table 2). This tendency of using natural gas almost not changed from 2000. Potentials of heat sector could be associated with wider biomass using. Wood part in fuel balanse increased to 10 percent. Using geothermal energy increased for individual house heating. So it’s possible to state that Lithuanian energy dependency of imported fuel decreased in heat sector.

Lithuania is one of the few European countries, which almost doesn’t have its own conventional energy resources (coal, oil, natural gas, uranium and large hydro energy resources). As said in the national energy strategy, the structure of primary energy resources, used in Lithuania in 2000-2005, is given in Figure 1. The main part of primary energy resources are imported in Lithuania in 2000-2005 (Figure 2).

The absolute majority of imported primary energy resources is obtained from Russia (natural gas—100 %, coal and peat—90.8 %, oil—91.8 %, nuclear fuel—100 %).

Nuclear fuel because of RBMK reactor specificity is imported only from Russia. Natural gas is supplied only from Russia, there are no other way to get it, we don‘t have liquid natural gas storage also. Oil products, coal and peat are supplied from Russia mostly, though they can be imported from other counties, for example, oil from Kazakhstan, orimulsion from Venezuela. So there is a big dependability from one country supplier.

So the main threats of Energy security of supply in Lithuania are:

- high level of supply of primary energy resources from one country (natural gas, nuclear fuel);
- closing of Ignalina NPP and takedown of it‘s reactors till installation of competitive power generating sources and implementing tools of energy supply network, especially intersystem connection to Poland and Sweden;
- old heat supply systems and electricity transmission network, slow modernization of technologies.

Those threats between others are showed in latest energy strategy of Lithuania.

Survey of Energy Security of Supply Analyses

In the literature it wasn’t found methodologies, which would include all energy safety of supply components: scenarios of disturbances, economical modeling, reliability modeling of supply systems, and analysis of consequences. It is mostly researching one or maximum two fields. Some of them analyses only one or two scenarios.

General equilibrium approach was used in USA by Tani (1978) in nineteen eighty's, when it was performed analysis of dependency on oil. It was made study of possibility to generate synthetic fuel. It used decision analysis scenario approach, where probabilities of scenarios where estimated by evaluation of experts. The criteria include:

- economic impact on consumers (consumer surplus),
- economic impact on producers (producer surplus),
- embargo protection,
- environmental and socio-economic impacts.

SRI-GULF model based on general equilibrium theory was created by Cazalet and others (1977). An algorithm of energy supply had included:

- processes of extraction of primary energy sources,
- transportation,
- conversion,
- saving, and
- supply.

Analysis showed that synthetic fuel generation would bring loss of energy economy. The modeling showed strong and week places of energy sector.

Economic modeling approach was used by Suzuki (1998) in Japan, when it was set objective to research energy sector dependability on natural gas.

Scenarios: basic and alternative , which includes increased emphasis on substitution of natural gas for coal and oil in both end-use demand sectors and electric power generation, plus aggressive application of end-use efficiency improvement and renewable fuels in all sectors.

There was used LEAP (Long-range Energy-environment Alternatives Planning) model, which evaluate internal and (some) environmental costs of energy-sector changes. The model is not an optimizing model, but candidate variants of energy paths can be quickly assembled and tried in order to meet specific criteria (such as cost, fuel diversity, or environmental constraints). Analysis showed that alternative scenario was better.

Assessment of interdependencies was used of Finland scientist Suzuki (1998) calculating which energy sector is the most meaningful for others. There were evaluated risk that causes interaction of technical infrastructures and external threats.

Calculations of complex risk, based on interconnections of critical infrastructures, were used. There were also used linear mathematical modeling and assessment of interdependences. Common dimensions of assessment were:

- Capacity redundancy;
- Availability redundancy;
- Controllability of the country;
- Security arrangement;
- Preparedness planning.

Results of modeling: probability of at least one failure per year; influence of at least one day failures; complex risk of one year.

There were defined that electricity sector would have the biggest influence to other sectors.

Moldovan scientist Bykova E. V. (2005) was performed analysis of indicators of energy supply security. She grouped indicators to different blocks, estimated critical and non-critical values of security indicators, aggregated important proportion of indicators, set normalization of them, performed sensitive analysis of indicators in critical situations, set functional systems of equations, which consists parameters energy security of supply.

There was performed analysis of USA experts leading by Beccue (2005). It is based on decision analysis and probabilities evaluated by experts.

Risk assessment was performed on workshops. Experts of geopolitics, war, oil market participated. They estimated probabilities of different events and their feedback to main disturbances in oil market.

To facilitate the assessment, there were conducted the following steps:

1. Brainstorm factors;
2. Categorize into regional vs. broader underlying events (which impact multiple regions);
3. Develop influence diagrams to identify the relationships between events;
4. Develop scales for each event to define two or more states;
5. Assign likelihoods for each state;
6. Combine mathematically by analyzing all combination of outcomes and weighting them according to probability inputs from experts.

The risk assessment required probability inputs for six variable types:

- Global underlying events;
- Regional internal factors, shortfall amounts, duration;
- Future oil production; and,
- Excess capacity.

The approach allows interdependencies to exist between events, thereby providing a richer evaluation of the underlying risks of disruptions. The assessment incorporates expert judgment to provide an explicit quantification of the magnitude, duration and likelihood of oil supply events that could cause significant upward deviations in world oil prices.

Expert evaluation requires considerable experience in appropriate techniques for uncovering unbiased responses from workshop participants.

The decision analysis approach to capturing judgmental uncertainty is to model the assessed quantity in detail by decomposing it into well-defined components, assessing lower level probabilities, and then combining the data mathematically. Advantages of this approach are 1) assessments are easier, 2) it facilitates assessments with groups of experts, 3) the quality of assessments tends to be high, and 4) logic and assumptions are well documented. Disadvantages are a tendency to go too far in the level of detail of modeling the problem, and the fact that the approach can be time intensive.

So the problem is the absence of full methodology to evaluate allowable energy supply strategic dependency on supply quantitatively from country, which can be reputed as unreliable supplier or try to use supply of energy or other raw material in political purposes. The criteria or methods that are created and available solve economical, political or technical problems for choice.

Principles of Energy Supply Security Methodology

The aim of the work is to create a methodology for estimating energy security of supply in Lithuania. The presentation includes a short presentation of Lithuanian energy security problems, short survey of a few energy security analyses, and review of principal scheme of methodology proposed for analysis of energy security of supply. The methodology of energy supply security will be created for Lithuania for the first time. We would like to create full methodology, which would be well reasoned by scientific methods.

Researched threats of Lithuanian energy sector such as dependability of one country supply, historical political of supplier unreliability, closing the main power generation plant, absence of network with west Europe. The serious threats forces to choose full methodology of energy supply security research, which include all parts of security analysis: scenarios of disturbances, economical modeling, reliability of technical systems modeling, consequences analysis.

For analysis of scenarios of disturbances we need such input data as statistical data of breaking of energy security of supply; evaluation of experts. The most probable evaluation of experts should be selected using Fuzzy logics, Bayesian approach, Decision analysis or possibilities theory. Results of the analysis are disturbance scenarios and evaluated their appearance probabilities. Also t here should be separated: short term scenarios evaluate real state and short breaks of supply because of transmission system failures and political disturbances; long term scenarios evaluate new technologies (by example: new power plants) influence to ESS.

Economical modeling lets evaluate economical benefit of the scenario. Economical models BALMOREL, EFOM, MESSAGE are optimization, bottom-up (sources/technologies-needs), dynamic models. We started to use MESSAGE computational tool described by Norvaisa (2004). The tool is designed for planning energy sector in long perspective, where could be predictable technological process. Its optimization function is minimization of work of energy system during the considered period.

Using model it is possible to assess and compare different energy development strategies, alternatives of using different energy resources or new energy technologies. Applying sensitivity analysis it is possible to investigate the influence of particular indicators to functioning of energy system.

The main result of modeling useful for energy security of supply is quantity of costs of energy system, then limitations of primary energy resources, of environment, of policy exists.

Reliability analysis evaluates the influence of networks and systems of energy transmission to energy safety.

Simulating Lithuanian power transmission network model:

- shows operating of network then natural or simulated occurred;
- analyses natural or simulated failure scenarios when separate elements (transfer lines, substations, generators) are eliminated from the network.

Results for ESS evaluation scale:

- quantity of unsupplied energy,

- energy break time,
- “cascade” effects of energy system failures,
- unreliable links of the system,
- time of system renovation after breakdowns.

Probabilities of consequences evaluated using statistical data and experts approach. In decision analysis, sequences are examined of decisions and uncertain events. A decision tree is often used as a visual display and a computing device for computing the probability distributions corresponding to different decision alternatives, and then evaluating these to find the best decision. Results of the consequence analysis are scenarios of possible consequences and probabilities of failures. Consequences can also be classified to critical and safe. The most likelihood consequences can be found using sensitivity analysis.

All scheme of the methodology is presented in Figure 3.

Parameters of Energy Supply Security Scale

Another field of scientific research is related to energy security assessment system, development of the system of security indicators, analysis of results uncertainties and interpretation. According to the system of energy security assessment results of every scenario calculated would be valuated in security scale. Security measure should be single and involve technical, economical, environmental, and political criterions.

The method of using economical indicators is proposed by Moldavian scientist Bykova (2005). The grouping of indicators devices on blocks describing whole process of power supply of consumers is offered in the present work (Figure 4).

The main indicators are the most representative indexes which are included in state and the departmental reporting of enterprises and the power enterprises provided of input dates.

The system from indicators has obtained by transformation of primary indicators reflecting activity of power system is formed for research of energy security of Lithuania.

The indicators like fuel consumption for one resident and part of the dominant kind of fuel in total supply of fuel would consist the block of fuel supply.

The block of energy generation consists of such indicators as generated quantity power and heat energy for one resident; own primary energy resources part in total balance; capacity part of power plants that can immediately get power in general installed capacity (for example, Kruonis hydropower plant in Lithuania); part of cogeneration power-plants capacity in total capacity; part of the biggest power plant; reserve part in the installed capacity.

Parameters of block of energy transmission and distribution electric energy would be amortization level of substations, their connectors and their transformers.

In the block of energy import should be researched such parameters as reserve level of intersystem connections, reserve level of power system, import value per capita of consumed electric energy.

In ecological block the main parameters are ejection level of carbon dioxide per capita of burnt fuel and for one resident.

Critical factors of consumption block are electric and heat energy consumption per resident; ration between supply costs of fuel/energy and averaged income of residents.

Block of finances and management would include the parameters: the level of consumers'/companies' debt comparing with costs of consumed energy resources; total level of debit/credit debts compared with costs of consumed energy resources.

Besides these economical indicators authors would suggest to use blocks of: reliability of network, geopolitical, social and political parameters.

Reliability of network block includes such important factors: reliability of energy supply system; hazards because of human actions; external events (the main: falling of aircraft, extreme wind and tornado, flood and strong rain, seismic events; external fire; attack of turbine splinters; loss of external electric energy supply).

The main geopolitical indicators are: diversification of energy sources; diversification energy suppliers and routes.

The major social indicators could be the level of satisfaction of consumer demand; position of consumers to energy security of supply and education.

Very important political indicator is political relations with states, supplying energy.

Assessing threshold values of energy security indicators can be used in two ways: 1) method of expert assessment of threshold values; 2) method of functional dependability of indicators.

Using first method the values established by experts of our or other countries are chosen as threshold (critical or pre-critical) values.

The levels of threshold values of indicators of energy security which find by the expert mode and use for the analysis of indicators have the demerit—subjectivity of judgments of the experts. Though this can be assessed using Fuzzy logic or Bayesian methods.

The threshold values of indicators define boundary of crossing in the state of crisis that is mapped with the help of the scale of crisis, which is divided into intervals of the normal and crisis state with selection area before crisis (Figure 5).

The each interval of the scale has the mark of state:

- 1 (normal);
- (state before crisis with separation on initial, extending and critical);
- (state of crisis with dividing on unstable, menacing, critical and extreme).

The state of each indicator is determined on the scale of crisis the way by comparison of its numerical value with values dividing intervals.

The mark allows receiving an integrated estimation on blocks, regions and on the country as a whole. Besides such estimation is convenient in the series of cases when for decision of problem enough to know the indicator's interval of crisis instead of its precise value.

Using method of functional dependency:

- Threshold values of energy security are receivable by interdependency of indicators. For making threshold values is using the value of 50 percent GDP of basic year and values of experts.
- Normalization of values is performed for availability to compare values

$$\textit{Normalized value of indicator} = \frac{\textit{factual value of indicator}}{\textit{critical threshold value}}$$

- The most sensitive indicators are found by experts.
- It is created functional dependency of indicators of energy security of supply from economical indicators and conversely.

Using the methodology of indicators it is possible to compare different scenarios of energy supply.

Conclusions

It is used different methodologies for research of energy supply security by detail and by size.

The choice of methodology for particular country depends on its complexity of energy networks with other countries. It shows analysis of country main threats.

Lithuanian situation of energy safety of supply compared to other European countries is quite complicated because of few countries supplying primary energy sources (for the most part is supplying from Russia). That's because in Lithuania it have be completed full energy supply analysis, including stages: scenarios of disturbances, economical modeling, reliability of supply systems, consequences analysis. All these stages are very important performing Lithuanian analysis. Consequences to Lithuanian economy should be rated in general scale of indicators. In the short run Lithuania have to take important decisions—construction of power plants, including NPP, and this have to be based on scientific estimation of energy security of supply.

About the Authors

Juozas Augutis is a Professor, Habil. Dr. whose fields of scientific interest include: probability theory, risk analysis, reliability, and energy security. Positions include: Chief Research Associate (1991-present), Lithuanian Energy Institute; Professor at the Mathematics and Statistics Department (1991-present); Vytautas Magnus University; Vice Rector for Researches (2006-present), Vytautas Magnus University. Education: Bachelor Studies, Vilnius University (1973-1978), Faculty of Mathematics and Mechanics; PhD Studies (1981-1985), Kaunas Technological University; Habil. Dr. (2002), Technological Sciences. Experience in consulting, expert's and other activities (1991-present): development of mathematical models for evaluation of frequencies and consequences of such events: floods, strong wind, plane crash, external fire. In 2006 he was elected as expert of Lithuanian academy of sciences. He is a chairman of Ignalina NPP security committee, expert of Lithuanian State Science and Studies Foundation, expert of science council of Lithuania, expert of 6BP projects, member of Lithuanian energy institute and Institute of mathematics and informatics. In 2005 he have got Lithuanian national science premium.

Vaida Matuziene is a PhD student whose fields of the scientific interest include: research and evaluation of energy security of supply; system analysis of economical and social elements. Positions include: junior research associate (2004-present), Lithuanian energy institute; assistant, Vytautas Magnus university. Education: Bachelor of Science in Mathematics (1996-2000), Siauliai University; Master of Science in Applied Mathematics (2000-2002); Doctoral studies of energy and thermo engineering science field (2004-presently), Lithuanian energy institute. Participation in Leonardo da Vinci project UNDERSTAND, which the main aim is to develop and maintain standards of energy security of supply on critical moments; consult and teach to different specialists: representatives of energy companies; scientists and politicians. Participation in development of the research study "Development of safety and reliability methodologies of energy supply for Lithuania." The aim of the work is to create methodology of evaluation of Lithuanian energy security of supply based on scientific methods.

Tables and Figures

Table 1: Maximum possible flows of capacity to neighboring countries, MW

Lithuania- Latvia	1540
Latvia – Lithuania	1170
Lithuania- Belarus	1850
Belarus – Lithuania	970
Lithuania – Kaliningrad district of Russian Federation	650

Table 2: Dynamics of fuel input, %.

	2000	2001	2002	2003	2004	2005	2006
Natural gas	80.1	72	75.5	82.3	83.6	83.7	80.6
Renewable energy resources	2	4	5	7.2	10	9.9	12.2
Oil	17.2	22.7	18.7	9.7	5.6	5.3	5.35
Other fuel	0.6	1.3	0.8	0.8	0.8	1.1	1.85

Figure 1: The dynamics of primary energy resources used in Lithuania 2000-2005.

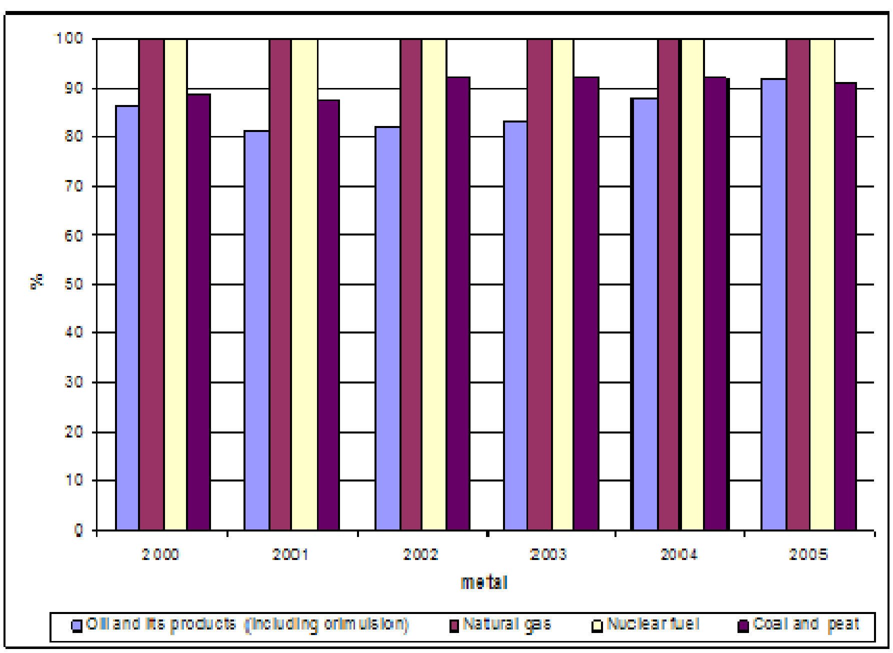


Figure 2: The part of imported primary energy resources used in Lithuania 2000-2005.

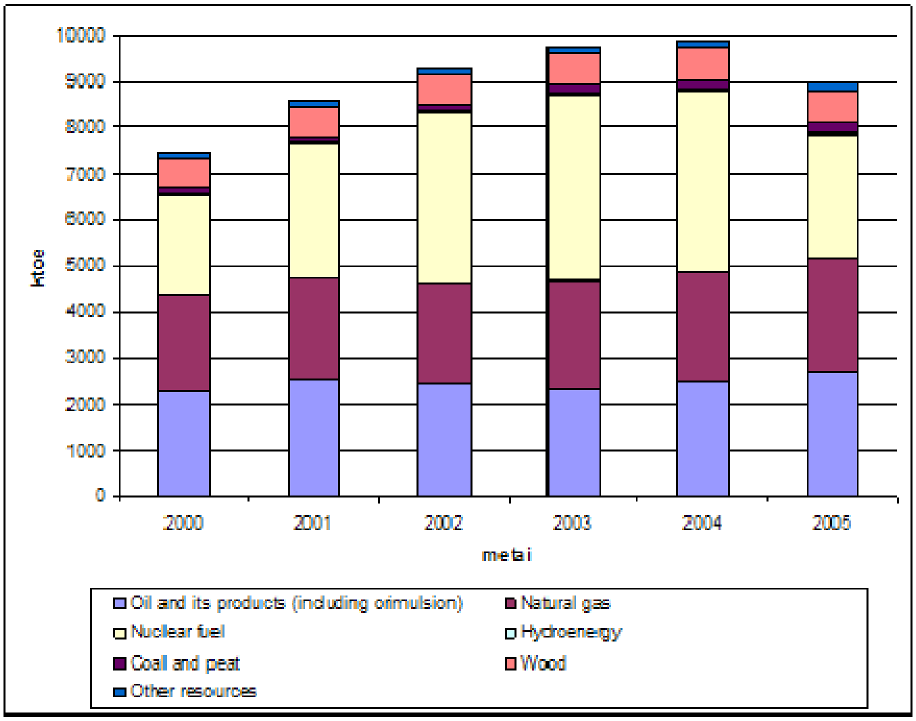


Figure 3: The scheme of full suggested methodology

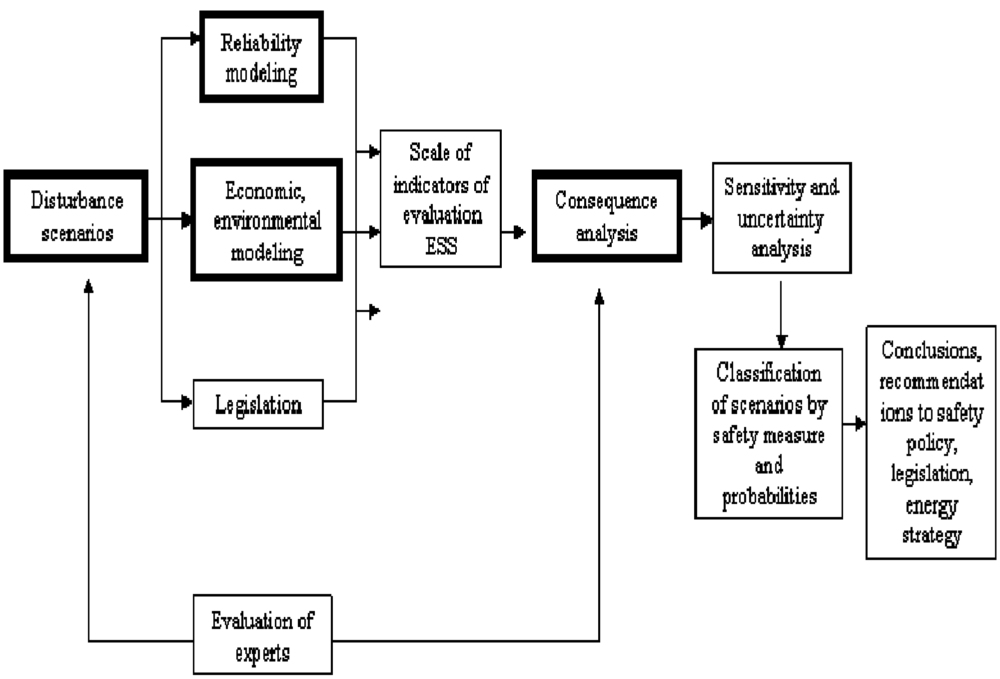


Figure 4: The inter-structure of economical indicators blocks of energy supply of security

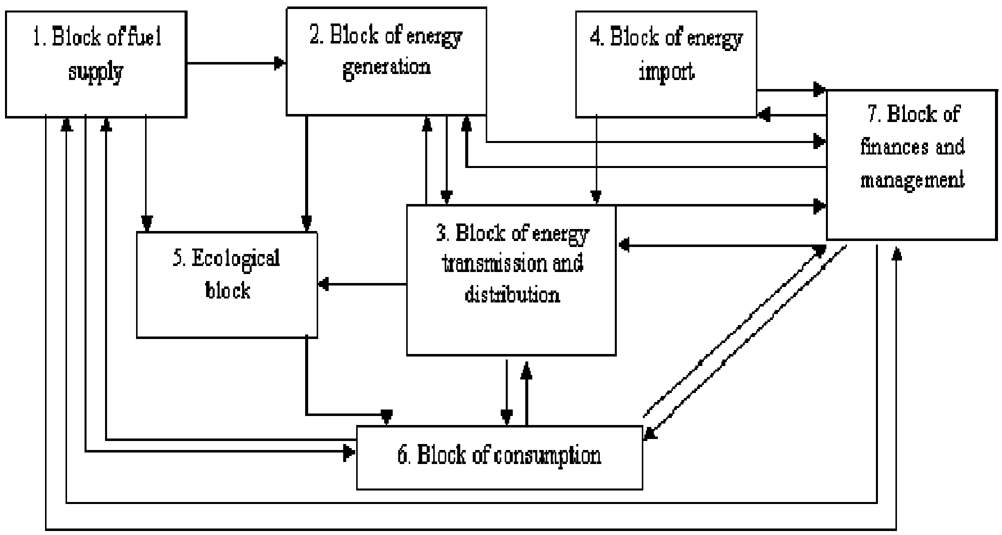
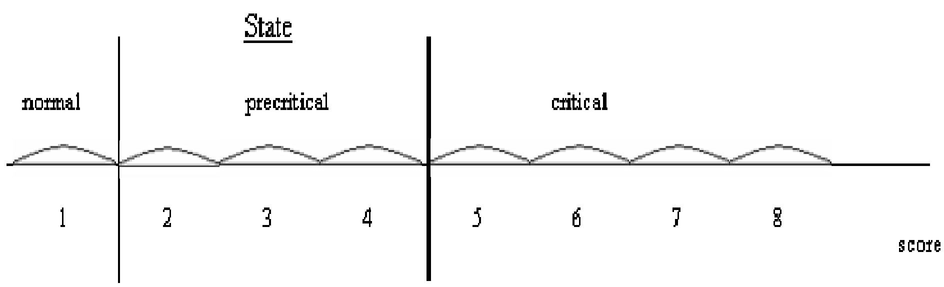


Figure 5: The threshold values of indicators



For more insights into contemporary international security issues, see our *Strategic Insights* home page.

To have new issues of *Strategic Insights* delivered to your Inbox, please email ccc@nps.edu with subject line "Subscribe." There is no charge, and your address will be used for no other purpose.

Sources

1. Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy, Brussels, 2006.

2. Revised and renewed national program of energy consumption and efficiency increasing. Confirmed by order of LR economy minister No. 319, October 26, 2001.

3. National energy strategy. Certified by resolution of LR parliament No. X-1046, January 18, 2007. Online at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=291371.

4. Lithuanian energy institute. Energy in Lithuania 2004 m., 2005 m. Compiled by A.P.Juska and V.Miskinis—2005, 2006.

5. Tani S. N. Decision *Analysis of the Synthetic fuels Commercialization Program* // Proc. of the National Computer Conference, 1978, AFIPS 47, pp. 23-29.

6. *Generalized Equilibrium Modeling: The Methodology of the SRI-GULF Energy Model*. Prepared by Cazalet E. G. and Stanford Research Institute. Final Report, May 1977.

7. Suzuki T., Hippen D. V. *A Framework for Energy Security Analysis and Application to a Case Study of Japan*. Synthesis Report for the Pacific Asia Regional Energy Security (PARES) Project, Phase 1, 1998.

8. Sivonen H. *Calculating Compound Risk of Failure Based on Interdependencies of Critical Infrastructures*. EAPC. PfP Workshop on Critical Infrastructure Protection and Civil Emergency Planning in Zurich on 9-11 September 2004.

9. Bykova E. V. *The methods of calculation and the analysis of indeles of energy security*. Monograph, 2005.

10. Beccue F. C. *An Assessment of Oil Market Disruption Risks*. Final report, Stanford University, 2005.

11. Norvaisa E. Modeling and Analysis of Sustainable Development of Lithuanian Power and Heat Supply Sectors. Doctoral thesis, Kaunas 2004.